

OECD GUIDELINE FOR THE TESTING OF CHEMICALS

Viscosity of Liquids

INTRODUCTION

1. This Test Guideline is a revision of the original Test Guideline 114 adopted in 1981. This revision harmonizes methodology among several guidelines.
2. OPPTS 830.7100 (1) and CIPAC MT 3 (2) cite various methods for the determination of viscosity. Most of the methods listed are appropriate for the investigation of Newtonian fluids. The measurement of a non-Newtonian fluid is performed via rotational viscometry as described in CIPAC MT 192 (3). The first two guidelines above specify that the determination of viscosity should be performed at a temperature of 20°C and at one other temperature approximately 20°C higher. The REACH guidelines for chemical safety assessment and CLP regulation (EC) specify viscosity be determined at 40°C (4).

INITIAL CONSIDERATIONS

3. Most methods for determining the viscosity of liquids are the object of national and international standardizing bodies and are frequently specified by governmental agencies. This Test Guideline provides procedures that embrace the methodology of the standardizing bodies and the requirements of governmental agencies.
4. Density of a liquid is a prerequisite for the rolling ball viscometer method.

SIGNIFICANCE

5. This Test Guideline provides procedures to obtain viscosity of liquids and liquid mixtures. The data may be used to assess the manner and extent that liquids and components of mixtures will be transported in the environment and locations where they will likely be deposited. The data may also be used in the assessment of human safety of the liquid and the mixture.
6. These methods are capable of greater precision than is likely to be required for environmental assessment. The measurement ranges of various viscometers are summarized in Table 1.

DEFINITIONS AND UNITS

7. Viscosity of a fluid is the measure of the property of a fluid substance of absorbing a stress during deformation which depends on the rate of the deformation. Similarly, the stress can be regarded as the cause which brings about a deformation rate.

8. The shear stress τ and the shear rate D are related by the equation.

$$\tau = \eta D$$

where η is the dynamic viscosity.

9. For Newtonian liquids, the viscosity is constant at all shear rates and depends only on the variables pressure and temperature.

10. For non-Newtonian liquids, the viscosity will vary with shear rate. If the viscosity is measured with capillary viscometers without applied pressure, the measured quantity obtained, kinematic viscosity (ν), is the ratio of dynamic viscosity to density ($\nu = \eta / \rho$).

11. The SI unit of shear stress τ is the Pascal, Pa. The SI unit of shear rate D is per second, s^{-1} . The SI unit of dynamic viscosity is the Pascal second, Pa.s. For practical use a sub-multiple is more convenient; 1 mPa.s = 10^{-3} Pa.s (one centipoise [cP] in the obsolete cgs system.)

12. The SI unit of kinematic viscosity is the square metre per second, m^2/s . The normal subunit derived from this is the square millimetre per second, $mm^2/s = 10^{-6} m^2/s$. (1 $mm^2/s = 1$ centistoke [cSt] in the obsolete cgs- system.)

REFERENCE SUBSTANCES

13. The reference substances need not be employed in all cases when investigating a new substance. They are provided primarily so that calibration or verification of the apparatus may be performed from time to time and to allow comparison with results using other methods.

14. The list of reference substances for viscosity on the next page has been extracted from that recommended by the International Union of Pure and Applied Chemistry (IUPAC) (5).

List of reference substances (extract from IUPAC list) (4)

Chemical name (identification)	Certified Value and accuracy	Source*	Remarks
Series of mineral oils (hydrocarbons, partly natural, partly synthetic products)	1 mPa.s to 27,000 mPa.s (1.25 mm ² /s to 30,000 mm ² /s) at 20°C. Uncertainty $\pm 0.2\%$, above 4000 mPa.s $\pm 0.3\%$	C	Newtonian liquids, determined by capillary viscometers with suspended level, (Ubbelohde). Data also for other temperatures between 20°C and 100°C
Type JS 2.5 -2000 (series of 10 liquids)	Certified for viscosity in mPa.s and kinematic viscosity in mm ² /s. Range for viscosity at 20°C from 2 to 1800.	E	
Type 60 H	60,000 mm ² /s at 20°C	E	
Type 200 H	200,000 mm ² /s at 20°C	E	
Mineral oil	11 mPa.s to 1000 mPa.s $\pm 0.1\%$ at 20°C	D	Newtonian liquid. Certified also for density and kinematic viscosity
Mineral Oil	10 ⁴ mPa.s to 10 ⁶ mPa.s $\pm 0.5\%$ at 20°C		
Polyisobutenes	10 ⁴ mPa.s to 10 ⁵ mPa.s $\pm 1.5\%$ at 20°C		Newtonian liquid. Rotating cylinder viscometer method used.
Series of 11 mineral oils	Certified for viscosity in mPa.s at 20°C. Range from 1.503 \pm 0.1% to 1729 $\pm 0.2\%$	G	Certified also for kinematic viscosity and density. Data also at 50°C and 80°C.
Series of 7 Polyisobutenes	Certified for viscosity in mPa.s at 20°C. Range from 4170 \pm 1.3% to 589 x 10 ³ $\pm 1.0\%$	G	Data also at 50°C, 80°C and 100°C

* Units are given as reported by issuing laboratory. The countries reporting:

C. Germany The Physikalische-Technische Bundesanstalt 33 Braunschweig, Bundesallee 100,
Federal Republic of Germany.

D. Hungary National Office of Measures Németölgyi ut 37-39, sz. Budapest XII, Hungary.

E. Japan	National Chemical Laboratory for Industry, Ministry of International Trade & Industry, 1-1 Honmachi, Shibuya-ku - Tokyo, 151 Japan.
G. Poland	Division of Physico-Chemical Metrology, National Board for Quality Control and Measures - 2, Elektoralna Street, Warsaw, Poland.

PRINCIPLE OF THE METHOD

15. Viscosity measurements are carried out predominantly according to three measurement principles:

- (a) The flow under gravity through a capillary (capillary viscometer or flow cup)
- (b) Shearing of the fluid between concentric cylinders, coneplate and parallel plate (rotational viscometer). The measurement is performed under different shear conditions and the apparent viscosities are determined.
- (c) Dynamic viscosity can be measured by movement of a ball in a vertical or inclined liquid-filled cylindrical tube (e.g. a rolling ball viscometer by Höppler, drawing ball viscometer, etc.). With the Höppler viscometer the density should be known in order to calculate the dynamic viscosity.

A fluid sample is transferred to a rotational viscometer (ISO 3219). The measurement is performed under different shear conditions and the apparent viscosities are determined. During the test the temperature of the fluid sample is kept constant at 20°C. The test is repeated at a temperature of 40°C. At least two determinations should be made at each temperature.

DESCRIPTION OF THE METHOD

Apparatus

16. Capillary viscometer designs are described in: ISO 3104; ISO 3105; DIN 51550; DIN 51562 Part 1; DIN 51366; DIN 53177; ASTM D-1200-; ASTM D-914 Sections 31 to 39; ASTM D-88.

17. The standardisation of rotational viscometers covers, with few exceptions, only general specifications concerning the flow pattern, range of shearing stresses to be used and velocity gradient as well as specification relating to specific substances. ISO 3219; DIN ISO 7884-2; DIN 51377; DIN 53214; DIN 53019 Part I; ASTM D-2196; ASTM D-562; ASTM D-3346; ASTM D-2983; CIPAC MT192 (2).

18. Rolling, falling or drawn ball viscometers are only standardised in such national standards as DIN 53015.

Test Conditions

19. During the test, the temperature of the fluid sample is kept constant at 20°C. The test is repeated at a temperature of 40°C. At least two determinations should be made at each temperature.

Quality Criteria

20. The various methods of determining viscosity of liquids are compared as to application, measuring range and standardisation in Table 1, below.

Table 1: Quality criteria

Method of Measurement	Viscosity Dynamic mPa.s	Viscosity Kinematic mm ² /s	Measuring range mPa.s or mm ² /s	Standardisation	Temperature constancy required °C
Capillary Viscometer		X	0.5 to 10 ⁵	ISO 3104	±0.1
Flow Cup		X	8 to 700	ISO 3105	±0.5
Rotational Viscometer	X		10 to 10 ⁹	ISO 3218.2	±0.2
Rolling Ball Viscometer	X		0.5 to 10 ⁵	No international standards see DIN 53015	±0.1
Drawing Ball Viscometer	X		0.5 to 10 ⁷	No international standards see DIN 52007 part 2	±0.1

Performance of the Test

21. The measurement is carried out according to the specifications in the respective standards.

DATA AND REPORTING

22. The viscosity measurement is to be carried out according to the standards in the case of capillary and forced ball viscometers. In the case of rotational viscometry, the specification of a viscosity is appropriate only for Newtonian fluids. For non-Newtonian fluids the results obtained are preferred in table or graph form, preferably in the order of increasing shear rates.

23. Report all measurement conditions such as temperature, type of instrument and measuring system and pre-conditioning treatment of the sample. The test report should include individual and mean values at each temperature. Any variation from the standard method should be described in detail.

LITERATURE

1. United States Environmental Protection Agency (EPA) (1996), *Product Properties Test Guidelines OPPTS 830.7100 "Viscosity,"* EPA 712-C-96-032.
2. Collaborative International Pesticide Analytical Council, Ltd. (CIPAC) (1995), *Handbook F, "MT 3 "Specific Gravity, Density and Weight per Millilitre,"* CIPAC (<http://www.cipac.org>), CIPAC Publications available from: Marston Book Services Ltd.: (<http://www.marston.co.uk>)
3. Collaborative International Pesticide Analytical Council, Ltd. (CIPAC) (2005), *Handbook J "MT 192 Viscosity of Liquids by Rotational Viscometry"* CIPAC (<http://www.cipac.org>), CIPAC Publications available from: Marston Book Services Ltd.: (<http://www.marston.co.uk>)
4. European Chemicals Agency (2008), Guidance on information requirements and chemical safety assessment, Chapter R.7a: Endpoint specific guidance, *Guidance for the implementation of REACH*, European Chemicals Agency.
5. International Union of Pure and Applied Chemistry (IUPAC) (1976), Physicochemical Measurements: Catalogue of Reference Materials from National Laboratories, *Pure and Applied Chemistry*, Vol. 48, pp. 513-514, Pergamon Press, Oxford.